1.0 INTRODUCTION

This volume contains the purpose and scope of the assessment, a description of the general characteristics of flame retardants, a general overview of exposure pathways and routes for flame retardants used in flexible polyurethane foam and the results of the assessments of 14 formulations of flame-retardant products most likely to replace commercially available pentabromodiphenyl ether (pentaBDE).

A second volume, subtitled, “Chemical Hazard Reviews,” consists of the complete data sets for each of the chemicals of the 14 formulations of flame-retardant products evaluated in this study. Volume 2 is available under a separate cover at http://www.epa.gov/dfe/projects/flameret/index.htm.

1.1 Purpose of the PentaBDE Alternatives Analysis

A significant quantity of the residential upholstered furniture sold in the United States contains low-density, flexible polyurethane foam. Without some form of fire protection, the foam is highly flammable. To address this safety issue, mandatory flammability standards and regulations have been enacted for residential upholstered furniture in California. California, Illinois, and Ohio have flammability standards for commercial furniture as well. The Upholstered Furniture Action Council (UFAC), an all-industry group, has also implemented voluntary standards for resistance to ignition from smoldering cigarettes. Most foam and furniture flammability standards and regulations (domestic and foreign) are performance based and do not specify particular chemicals or methods to achieve flame retardancy. Therefore, chemicals are not specifically required; rather, any method (chemical or product design) that achieves the standard is acceptable. Historically, halogenated flame-retardant chemicals, both brominated and chlorinated, have been used as a cost-effective method to meet standards without compromising product quality.

Polybrominated diphenyl ethers (PBDEs) make up a category of structurally similar chemical flame retardants, which are used in a variety of applications. The application of the individual PBDE varies according to the number and location of bromine atoms attached to the diphenyl ether. There are ten possible sites for bromine to bind, decabromodiphenyl ether representing full saturation. The structure for pentaBDE contains five bromine atoms ($C_{12}H_5Br_5O$). The bromine atoms can be bound to any of the carbon atoms, resulting in several possible isomers of pentaBDE (some of which are much more chemically stable than others). Figure 1-1 shows a generic figure for all PBDEs, where “m” and “n” refer to the number of bromine atoms bound to each aromatic ring. If $m + n = 5$, the resulting structure is a pentaBDE isomer.

Commercially available pentaBDE is actually a mixture of PBDE congeners where the primary component is pentaBDE. The remaining congeners typically include triBDE (0 to 1 percent), tetraBDE (24 to 38 percent), and hexaBDE (4 to 12 percent) (European Chemicals Bureau, 2001). For these congeners, $m + n = 3, 4,$ and 6 respectively. Unless otherwise noted, all references in this report refer to the commercial pentaBDE mixture rather than the pure pentaBDE chemical.

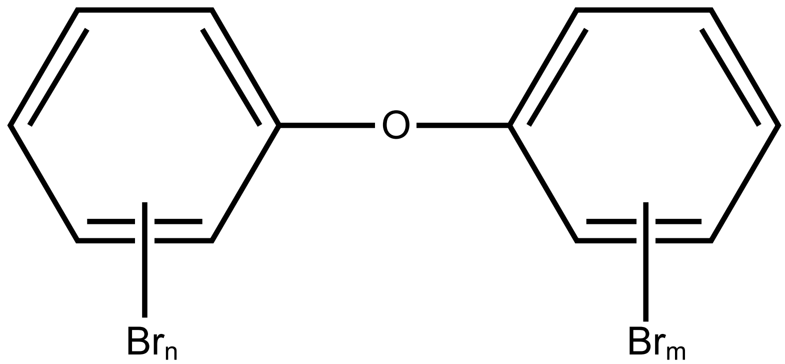

Figure 1-1 Pentabromodiphenyl Ether (pentaBDE), where m+n = 5

Brominated flame retardants (BFRs), such as pentaBDE, act by chemical interaction to prevent the spread of a fire. Combustion is typically propagated by a series of chemical reactions, where oxygen combines with chemicals in the burning product. BFRs interrupt some of these reactions by volatilizing halogen radicals to react with the product in place of oxygen, slowing combustion.

PentaBDE has been the primary flame retardant for low-density, flexible polyurethane foam in residential furniture and mattresses for several years. About 8,500 metric tons (18.7 million pounds) of pentaBDE is used each year worldwide (Peltola and Ylä-Mononen, 2000) with approximately 98 percent of that being consumed in North America (Environ International Corp., 2003). Although pentaBDE saves lives by retarding fires, there is growing concern over the persistence and bioaccumulation of pentaBDE that may originate from foam manufactured with this chemical. Information on the presence of pentaBDE in the environment and biota, and its effects can be found in Appendix A of this report. More information on pentaBDE can be found in the Agency for Toxic Substances and Diseases Registry (ATSDR) Toxicological Profile for Polybrominated Biphenyls and Polybrominated Diphenyl Ethers (Update) (ATSDR, 2004) and the Voluntary Children's Chemical Evaluation Program (VCCEP) Pentabromodiphenyl Ether Peer Consultation Meeting Report (TERA, 2004).

The European Union (EU) banned the use and sale of pentaBDE as of August 2004. Subsequently, the sole U.S. manufacturer of pentaBDE voluntarily phased out its production on December 31, 2004. In addition to the voluntary phase-out, legislation has been passed to prohibit the manufacturing, processing, or sale of substances or articles containing more than 0.1 percent by mass of pure pentaBDE in Hawaii and California in 2006 (January 1 and June 1, respectively).

The phase-out of production presents the need for alternatives to pentaBDE that are environmentally safer, economically feasible, satisfy fire safety requirements and meet industry's performance needs. In addition, the U.S. Consumer Product Safety Commission (CPSC) plans to implement new national fire safety standards regarding residential upholstered furniture that may lead to an increased need for flame-retardant furniture materials and an increased use of chemical flame retardants. The Furniture Flame Retardancy Partnership was formed as a result of this increased need to find practical alternatives that will suit the needs of all parties.

1.2 Scope of the PentaBDE Alternatives Analysis

Industry is actively exploring alternative methods to meet current and proposed fire safety standards. The Furniture Flame Retardancy Partnership is a project in which industry leaders have teamed with EPA and non-governmental environmental groups to evaluate each alternative based on human health, environmental, performance and cost considerations. The Furniture Flame Retardancy Partnership will identify the characteristics of the alternatives and anticipates that industry will choose flame retardants that perform well in each of these areas as full-scale replacements for pentaBDE.

To date, the Furniture Flame Retardancy Partnership has evaluated available toxicological information for replacements for pentaBDE in low-density, flexible polyurethane foam. These are flame retardants that are viable options for meeting the performance requirements of California's TB117 standard. This report includes information prepared for this short-term goal and presents it in a common format that will be directly useful to industry as replacement flame retardants are selected.

The Furniture Flame Retardancy Partnership also has longer-term goals that are not included in this report. The next phase of this project will look at flame-retardant options for meeting the planned CPSC flammability standard for residential upholstered furniture. In the future, the Furniture Flame Retardancy Partnership intends to develop a process to identify additional toxicological data needed for adequately assessing the pentaBDE alternatives that attain a significant market share. This effort will help industry to develop a common level of toxicological information for such flexible foam flame retardants. The Partnership also intends to encourage development of safer flame retardants through high-level EPA recognition.

Alternative flame retardants can be separated into two categories: alternative chemicals and alternative technologies. The ideal chemical alternative would be a drop-in replacement that has similar physical and chemical properties to pentaDBE formulations such that existing storage and transfer equipment as well as foam production equipment can be used without significant modification. Most pentaBDE formulations are liquid, so most U.S. foaming operations are currently equipped to use liquid streams in the production of foam. Any chemical substitute that is not a liquid or is extremely viscous will require most U.S. operations to alter existing equipment – at significant cost – to accommodate the new chemical. If the alternative is not compatible with existing process equipment at foam manufacturing facilities, the plants will be forced to modify their processes and potentially have to purchase new equipment. Holding cost and feasibility as significant considerations, this report has focused on evaluating several of these potential drop-in chemicals.

Four chemical manufacturers have identified viable formulations for EPA review. These formulations are listed in Table 1-1. The chemicals in each formulation were screened for potential toxicological and environmental hazards as well as for potential exposure. A summary of the evaluations of this data is organized in Table 4-1 in Section 4.

The data presented on the formulations provide a means for comparison and allow the reader to conduct a screening-level hazard evaluation for each chemical alternative. Chemical release points and associated exposure routes and pathways for flame-retardant chemical manufacturing facilities, foam manufacturing facilities and furniture manufacturing facilities are included in Section 3 of this report.

Table 1-1 Potential Flame-Retardant Chemical Formulations

Albemarle Corporation	Ameribrom, Inc. (ICL Industrial Products)	Great Lakes Chemical Corporation	Supresta (Akzo Nobel)
SAYTEX® RX-8500	FR 513	Firemaster® 550	Fyrol® FR-2
SAYTEX® RZ-243		Firemaster® 552	AB053
ANTIBLAZE® 195			AC003
ANTIBLAZE® 205			AC073
ANTIBLAZE® 180			
ANTIBLAZE® V-500			
ANTIBLAZE® 182			

Non-chemical alternatives that eliminate the need for pentaBDE are addressed in Section 5.5 of this report. Though these technologies may not be considered feasible for immediate implementation or application for flame retarding foam, these alternative technologies are being considered for further investigation by the Furniture Flame Retardancy Partnership. Three currently available, alternative technologies for flame retarding furniture include barrier technologies, graphite impregnated foam and surface treatment. There is considerable interest in future applications of these technologies for the furniture industry.

This report is intended to provide information that will allow industry and other stakeholders to evaluate environmentally safer alternatives for flame retarding furniture. The report is organized as follows:

- *Section 1 (Introduction):* This section provides a background to the Furniture Flame Retardancy project including the purpose and scope of the Partnership and of this report.

- *Section 2 (Chemical Flame Retardants):* This section describes characteristics of the flame-retardant chemicals currently used in flexible polyurethane foam and the mechanisms by which they suppress fires.

- *Section 3 (Exposure):* This section provides a general discussion of exposure concerns that should be evaluated when conducting an environmental risk assessment and identifies exposure pathways and routes associated with flame-retardant chemicals used in furniture manufacturing.

- *Section 4 (Alternatives Evaluations):* This section contains EPA's exposure and hazard assessments on a chemical-specific and formulation-specific basis for the flame-retardant formulations being evaluated.

- *Section 5 (Considerations):* This section addresses considerations for selecting a replacement for pentaBDE based on environmental and economic feasibility. It also includes alternative technologies that may serve as alternatives to chemical flame retardants.